PATENT SPECIFICATION

(11) 1 337 621

DRAWINGS ATTACHED

1 337 621

(21) Application Nos. 133/71 and 134/71
(22) Filed 1 Jan. 1971
(23) Complete Specification filed 19 April 1971
(44) Complete Specification published 14 Nov. 1973
(51) International Classification F16C 17/10
(52) Index at acceptance F2A 2 7B2
(72) Inventors RAYMOND WILLIAMS and ROBERT EDWIN LECKENBY

(19) THE PATENT OFFICE LONDON

(54) IMPROVEMENTS IN AIR BEARINGS

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to journal and bearing assemblies which operate with gas lubrication between the journal member and the bearing member.

A typical form of gas bearing assembly of the type referred to above comprises a shaft and a co-operating bearing sleeve, the surface of the shaft and the bore of the bearing sleeve being finished to an extremely high standard of accuracy and smoothness to provide bearing surfaces between which gas lubrication can be maintained under normal operating conditions.

There are two main types of journal gas bearing assembly.

In the first type, which is known as a hydrostatic pressure fed journal gas bearing, gas lubrication is maintained between the bearing surfaces of the shaft and the bearing sleeve by gas which is fed under pressure from an external source to the interspace defined between the bearing surfaces.

In the second type, which is known as a hydrodynamic self-acting gas journal bearing, gas lubrication is maintained between the bearing surfaces of the shaft and the bearing sleeve by the pressure generated hydrodynamically in gas in the interspace defined between the bearing surfaces due to relative rotation of the shaft and the bearing sleeve.

Gas bearing assemblies of the kind referred to above can be made relatively cheaply, as disclosed in British Patent No. 979,731, by forming at least one of the bearing surfaces of the shaft and the bearing sleeve from a moulded plastics material such as an epoxy resin.

Both types of gas bearing assembly referred to above can be operated with the bearing sleeve rotatable on a stationary shaft or alernatively the shaft may be rotatable in a stationary bearing sleeve. In either case it is necessary to support the rotating member against longitudinal movement on the stationary member.

According to the present invention a journal gas bearing assembly comprises a shaft and a complementary bearing sleeve rotatable one relative to the other, the shaft and the bearing sleeve having co-operating bearing surfaces of a quality such that gas lubrication can be sustained between the shaft and the bearing sleeve, longitudinal movement of the shaft and the bearing sleeve one relative to the other in one direction being limited by a hydrostatic thrust bearing formed by a cushion of gas trapped under pressure in a closed volume located between co-operating thrust surfaces disposed on the shaft and the bearing sleeve, passage means leading directly into the closed volume for feeding compressed gas to the hydrostatic thrust bearing and a hydrodynamic thrust gas bearing formed by co-operating thrust surfaces on the shaft and the bearing sleeve acting in the opposite sense to which the hydrostatic thrust bearing acts between the shaft and the bearing sleeve for limiting longitudinal movement of the shaft and the bearing sleeve one relative to the other in the reverse direction.

The invention will be described further, by way of example with reference to the accompanying drawings; in which:

Figures 1, 2 and 5 are elevations of journal gas bearing assemblies having a bearing sleeve rotatable on a stationary shaft; and

Figures 3 and 4 are elevations of journal gas bearing assemblies having a shaft rotatable in a stationary bearing sleeve.

Referring to Figure 1 of the drawings a bearing assembly 1 is shown in which a hardened steel shaft 2 is supported by a

flexible mounting 3 in a structural member 4. The shaft 2 is surrounded by a close fitting bearing sleeve member 5 rotatable on the shaft 2. The bearing sleeve 5 has a blind ended bore which provides a trapped volume 7 between the blind end of the bearing sleeve 5 and the end of the shaft 2. The trapped volume 7 is of greater diameter than the bore 6 in order to accommodate an integral flange 8 on the end of the shaft 2. The flange 8 has a lower precision ground annular bearing surface 9 which is opposed by the face of an internal step 10 in the bore 6 of the bearing sleeve 5. The shaft 2 has a precision ground outer surface and the bore 6 of the bearing sleeve 5 has a plastics lining 11 formed with a surface of gas bearing quality complementary to the surface of the shaft 2. The bearing surface in the plastics lining 11 of the bearing sleeves may be formed for example by the method disclosed in our British Patent No. 979,731. The face of the internal step 10 in the bore 6 of the bearing sleeve 5 has a plastics coating 12 with a surface of gas bearing quality complementary to the surface 9 on the flange 8 of the shaft 2. The bearing surface of the plastics coating 12 is grooved to provide the gas pumping action between the bearing surfaces. Alternatively the metal bearing surface 9 may be grooved to achieve the same effect.

The shaft 2 is provided with a longitudinal internal air duct 13, the end of which leads into the trapped volume 7 and is sealed by a ball end-stop 14. A feed jet 15 of reduced diameter and located immediately below the ball end-stop 14 connects the air duct 13 into the trapped volume 7.

In operation of the bearing assembly 1 shown in Figure 1 the sleeve member 5 rotates on the shaft 2. The plastics lining 11 of the bearing sleeve 5 acts with the shaft 2 as a hydrodynamic air lubricated journal bearing, journal loads on the sleeve being supported by the pressurised cushion of air generated in the gap between the plastics lining 11 of the bearing sleeve 5 and the shaft 2 by rotation of the bearing sleeve 5 on the shaft 2. Compressed air is fed into the trapped volume 7 through the air duct 13 and the feed jet 15. The pressure of air built up in the trapped volume 7 provides a hydrostatic air bearing cushion supporting the bearing sleeve 5 longitudinally on the shaft 2 against end thrusts acting on the bearing sleeve 5 in the direction towards the shaft 2. The pressure of the air acting in the trapped volume 7 causes the bearing sleeve 5 to take up a position on the shaft 2 such that a small clearance exists between the bearing surface 9 on the flange 8 of the shaft 2 and the bearing surface of the plastics coating 12 on the step 10 in the bearing sleeve 5. The bearing surface 9 on the flange 8 of the shaft 2 and the bearing surface of the plastics coating 12 on the step 10 of the bearing sleeve 5 thus co-operate to act as a hydrodynamic air lubricated thrust bearing working counter to the longitudinal end thrust acting on the bearing sleeve 5 due to the pressure of the air in the trapped volume 7. The bearing assembly 1 can thus operate in any attitude and at the same time maintain precise location of the sleeve member 5 on the shaft 2. If a failure of the compressed air supply to the bearing assembly 1 should occur the ball end stop 14 ensures that a safe running condition can be maintained for a reasonable period of time.

The arrangement shown in Figure 2 is similar to the arrangement shown in Figure 8 and comprises a bearing assembly 16 in which a shaft 17 is supported by a flexible mounting 18 in a structural member 19. The shaft 17 is surrounded by a close fitting bearing sleeve member 20 which is rotatable on the shaft 17. The bearing sleeve 20 has a blind ended bore 21 which provides a trapped volume 22 between the blind end of the sleeve 20 and the end of the shaft 17. The trapped volume 22 is of greater diameter than the bore 21 in order to accommodate an integral flange 23 on the end of the shaft 17. The flange 23 has a lower precision ground annular bearing surface 24 which is opposed by the face of an internal step 25 in the bore 21 of the bearing sleeve 20. The shaft 17 has a precision ground outer surface and the bore 21 of the bearing sleeve 20 has a plastics lining 24 formed with a surface of gas bearing quality complementary to the surface of the shaft 17. The face of the internal step 25 in the bore 21 of the bearing sleeve 20 has a plastics coating 27 with a surface of gas bearing quality complementary to the bearing surface 24 on the flange 23 of the shaft 17. The surface of the shaft 17 is provided with machined pumping grooves 28 extending from the fixed end of the shaft 17 up to radial ducts 29 located mid way along the shaft 17. The ducts 29 extend from the surface of the shaft 17 to a longitudinal duct 30 in the shaft 17. The duct 30 leads from the ducts 29 to the end of the shaft 17 in thetrapped volume 22, the end of the duct 30 being sealed by a ball end stop 31. Immediately behind the ball end stop 31 a restricted feed jet 32 connects the duct 30 with the trapped volume 22. The surface of the plastics coating 27 on the face of the internal step 25 in the bore 21 of the bearing sleeve 20 is grooved to provide gas pumping action between the bearing surfaces. Alternatively the metal bearing surface 24 may be grooved to achieve the same effect.

In operation of the bearing assembly 16 shown in Figure 2 the sleeve member 20 rotates on the shaft 17 as a hydrodynamic air

lubricated journal bearing, journal loads on the sleeve 20 being supported by the pressurised cushion of air generated in the gap between the plastics lining 26 of the sleeve 20 and the bearing surface of the shaft 17 by rotation of the sleeve member 20 on the shaft 17 and by the action of the pumping grooves 28 on the shaft 17. The air pressure in the hydrodynamic journal bearing is at a maximum approximately mid way along the shaft 17. Thus compressed air is fed from the surface of the shaft 17 into the duct 30 by the ducts 29. From the duct 30 the air feed jet 32 feeds the compressed air into the trapped volume 22 to provide a hydrostatic air bearing cushion supporting the bearing sleeve 20 longitudinally on the shaft 17 against end thrusts acting on the bearing sleeve 20 in the direction towards the shaft 17. The pressure of the air acting in the trapped volume 22 causes the bearing sleeve 20 to take up a position on the shaft 17 such that a small clearance exists between the bearing surface 24 on the flange 23 of the shaft 17 and the bearing surface of the plastics coating 27 on the face of the internal step 25 in the bore 21 of the bearing sleeve 20. The bearing surface 24 and the bearing surface of the plastics coating 27 thus co-operate to act as a hydrodynamic air lubricated thrust bearing working counter to the longitudinal thrust acting on the bearing sleeve 20 due to the pressure of the air in the trapped volume 27. If the air supply to the trapped volume 22 is curtailed in any way the ball end stop 31 ensures that safe running conditions canbe maintained for a reasonable period of time.

Figure 3 shows a bearing assembly 33 comprising a bearing sleeve member 34 having a blind ended bore 35. The bearing sleeve 34 has an axial entension 36 by means of which the bearing sleeve 34 is supported by a flexible mounting 37 from a structural member 38. A shaft 39 is rotatable within the bore 35 of the bearing sleeve 34. The blind ended bore 35 of the bearing sleeve 34 provides a trapped volume 40 between its blind end and the end of the shaft 39. The trapped volume 40 is of greater diameter than the bore 35 in order to accommodate an integral flange 41 on the end of the shaft 39. The flange 41 has an upper precision ground annular bearing surface 42 which is opposed by the face of an annular internal step 43 in the bore 35 of the bearing sleeve 34. The shaft 39 has a precision ground outer surface and the bore 35 of the bearing sleeve 34 has a plastics lining 44 formed with a bearing surface of gas bearing quality complementary to the surface of the shaft 39. The face of the internal step 43 in the bore 35 of the bearing sleeve 34 has a plastics coating 45 with a surface of gas bearing quality complementary to the bearing surface 42 on the flange 41 of the shaft 39. The bearing surface of the plastics coating 45 or the complementary bearing surface 42 is grooved to provide the gas pumping action between these bearing surfaces wh n the shaft 39 is rotated.

The extension 36 of the sleeve member 34 is provided with an internal air duct 46, the end of which leads into the trapped volume 40 and is sealed by a ball end-stop 47. A feed jet 48 of reduced diameter and located immediately below the ball end stop 47 connects the air duct 46 into the trapped volume 40.

In operation of the bearing assembly 33 shown in Figure 10 the shaft 39 rotates within the stationary sleeve 34. The complementary gas bearing surfaces of the plastics lining 44 and the shaft 39 act as a hydrodynamic air lubricated journal bearing supporting journal loads with the pressurised cushion of air generated in the gap between the bearing surfaces. Compressed air is fed into the trapped volume 40 through the air duct 46 and the feed jet 48. The air pressure built up in the trapped volume 40 provides a hydrostatic air bearing cushion supporting the shaft 39 against downwards end thrusts in the bearing sleeve 34. The pressure of the air acting in the trapped volume 40 causes the shaft 39 to take up a position in the bearing sleeve 34 such that a small clearance exists between the bearing surface 42 on the flange 41 of the shaft 39 and the bearing surface of the plastics coating 45 on the face of the internal step 43 in the bore 35 of the bearing sleeve 34. The bearing surface 42 and the bearing surface of the plastics coating 45 thus co-operate to act as a hydrodynamic air lubricated bearing working counter to the longitudinal thrust acting on the bearing sleeve 34 due to the pressure of the air in the trapped volume 40. The bearing assembly 33 can thus operate in any required attitude and at the same time maintain precise longitudinal location of the shaft 39 in the sleeve member 34. If a failure of the compressed air supply to bearing assembly 33 occurs the ball end stop 47 ensures that a safe running condition can be maintained for a reasonable period of time.

The bearing assembly 49 shown in Figure 4 is similar to that shown in Figure 3 and comprises a bearing sleeve member 50 having a blind ended bore 51. The bearing sleeve 50 has an axial extension 52 by means of which the bearing sleeve 50 is supported by a flexible mounting 53 from a structural member 54. A shaft 55 is rotatable within the bore 51 of the bearing sleeve 50. The blind ended bore 51 of the bearing sleeve 50 provides a trapped volume

56. The trapped volume 56 is of greater diameter than the bore 51 in order to accommodate an integral flange 57 on the end of the shaft 55.

The flange 57 has an upper precision ground annular bearing surface 58 which is opposed by the face of annular internal step 59 in the bore 51 of the bearing sleeve 50. The shaft 55 has a precision ground outer surface and the bore 51 of the bearing sleeve 50 has a plastics lining 60 formed with a bearing surface of gas bearing quality complementary to the surface of the shaft 55. The face of the internal step 59 in the bore 51 of the bearing sleeve 50 has a plastics coating 61 with a surface of gas bearing quality complementary to the bearing surface 58 on the flange 57 of the shaft 55. The bearing surface of the plastics coating 61 is grooved to provide gas pumping action between these bearing surfaces when the shaft 55 is rotated. The surface of the shaft is provided with machined pumping grooves 62 extending from the open end of the bearing sleeve 50 up to radial ducts 63 located midway along the shaft 55 and extending from the surface of the shaft into a longitudinal duct 64 in the shaft 55. The duct 64 leads to the end of the shaft 55 and is sealed at its end. Immediately opposite the sealed end of the duct 64 a ball end stop 65 is located in the bearing sleeve 50. A feed jet 66 connects the duct 64 into the trapped volume 56.

In operation of the bearing assembly 49 shown in Figure 4, the shaft 55 rotates in the fixed bearing sleeve 50, hydrodynamic air lubrication being sustained between the bearing surface of the shaft 55 and the bearing surface of the plastics lining 60 of the bearing sleeve 50. Journal loads on the shaft 55 are supported by the pressurised cushion of air generated in the gap between the shaft 55 and the plastics lining 60 of the bearing sleeve 50. The pressure generated is due to rotation of the shaft 55 in the bearing sleeve 50 and due to the pumping action of the grooves 62 on the surface of the shaft 55. Maximum pressure is generated about mid way along the shaft 55 in the region of the radial ducts 63 in the shaft 55. Thus compressed air is fed through the ducts 63 and the longitudinal duct 64 in the shaft 55 is fed from the duct 64 through the air feed jet 66 into the trapped volume 56 at the blind end of the bore 51 in the bearing sleeve 50. This provides a hydrostatic air bearing cushion in the trapped volume 56 supporting the shaft 55 longitudinally against downwards end thrusts in the bearing sleeve 50. The pressure of the air acting in the trapped volume 56 causes the shaft 55 to take up a position in the bearing sleeve 50 such that a small clearance exists between the bearing surface 58 on the flange 57 of the shaft 55 and the bearing surface of the plastics coating 61 on the face of the internal step 59 in the bearing sleeve 50. The bearing surface 58 and the bearing surface of the plastics coating 61 thus co-operate to act as a hydrodynamic air lubricated thrust bearing working counter to the longitudinal thrust acting on the shaft 55 due to the pressure of the air in the trapped volume 56. If the air supply to the trapped volume 56 is interrupted the ball end stop 65 ensures that safe running conditions can be maintained for a reasonable period of time.

Referring to Figure 5, of the drawings a bearing assembly is shown comprising a steel shaft 70 rotatable in a stationary bearing sleeve 71. The bearing sleeve 71 is supported in an aperture 72 in a structural member 73 by two flexible mounting members 74. The shaft 70 is stepped in two parts, a main part 75 and a smaller diameter part 76. The bore of the bearing sleeve 71 is also stepped in two parts, a main part 77 complementary to the main part 75 of the shaft 70 and a smaller diameter part 78 complementary to the smaller diameter part 76 of the shaft 70. The surfaces of the parts 75 and 76 of the shaft 70 are precision ground and the main part 77 of the bore of the bearing sleeve 71 has a plastics lining 79 with a surface of gas bearing quality complementary to the surface ot the main part 75 of the shaft 70. The smaller diameter part 78 of the bore of the bearing sleeve 71 has a plastic lining 80 with a surface of gas bearing quality complementary to the surface of the smaller diameter part 76 of the shaft 70. A free space 81 is defined in the main part 77 of the bore of the bearing sleeve 71 between a shoulder 82 on the shaft 70 and a shoulder 83 in the bore of the bearing sleeve 71. An air feed port 84 of restricted cross section passes radially through the bearing sleeve 71 from the space between the two mounting members 74 for the bearing sleeve 71 to the free space 81 in the bore of the bearing sleeve 71. A compressed air inlet passageway 85 extends through the structural support member 73 to the space between two mounting members 74 for the bearing sleeve 71.

An end of the shaft 70 is fitted with a rotor 89.

A thrust collar 91 is fitted on the shaft 70 between the rotor 89 and the end face 92 of the bearing sleeve 71. The end face of the thrust collar 91 facing the end face 92 of the bearing sleeve 71 has a precision ground bearing surface 93. The end face 92 of the bearing sleeve 71 has a plastics, coating 94 formed with a bearing surface 95 of gas bearing quality complementary to the bearing surface 93 on the thrust collar 91. The bearing surface 93 on the thrust collar 91 and the bearing surface 95 of the plastics

coating 94 on the end face 92 of the bearing sleeve 71 together form a hydrodynamic thrust bearing supporting the shaft 70 longitudinally against end thrusts in the direction away from the rotor 89. To make the hydrodynamic thrust bearing self acting radial pumping grooves are formed in either the bearing surface 93 or the bearing surface 95. Support for the shaft 70 against end thrust acting in the direction towards the rotor 89 is by a cushion of compressed air trapped in the free space 81 in the bore of the bearing sleeve 71. Air is admitted into the space 81 at a preset pressure.

WHAT WE CLAIM IS:—

1. A journal gas bearing assembly comprising a shaft and a complementary bearing sleeve rotatable one relative to the other, the shaft and the bearing sleeve having co-operating bearing surfaces of a quality such that gas lubrication can be sustained between the shaft and the bearing sleeve, longitudinal movement of the shaft and the bearing sleeve one relative to the other in one direction being limited by a hydrostatic thrust bearing formed by a cushion of gas trapped under pressure in a closed volume located between co-operating thrust surfaces disposed on the shaft and the bearing sleeve, passage means leading directly into the closed volume for feeding compressed gas to the hydrostatic thrust bearing and a hydrodynamic thrust gas bearing formed by co-operating thrust surfaces on the shaft and the bearing sleeve acting in the opposite sense to which the hydrostatic thrust bearing acts between the shaft and the bearing sleeve for limiting longitudinal movement of the shaft and the bearing sleeve one relative to the other in the reverse direction.

2. A journal gas bearing assembly as claimed in claim 1 in which the shaft is fixed and the bearing sleeve is rotatable on the shaft.

3. A journal gas bearing assembly as climed in claim 1 or 2 in which the compressed gas is fed from an external source into the closed volume.

4. A journal gas bearing assembly as claimed in claim 1 or 2 wherein the means for feeding compressed gas to the hydrostatic thrust bearing comprises a passageway in the shaft leading from the bearing interspace between the surface of the shaft and the bore of the bearing sleeve to the closed volume.

5. A journal gas bearing assembly as claimed in claim 4 wherein pumping grooves are provided on the surface of the shaft or in the bore of the bearing sleeve, the passageway leading from the pumping grooves to the closed volume.

6. A journal gas bearing assembly as claimed in claims 4 and 5 in which the passage way connects with the closed volume through an orifice of restricted cross-section.

7. A journal gas bearing assembly as claimed in any preceding claim wherein the bore of the bearing sleeve has a blind end and leads through a step into a part of larger diameter at the blind end of the bore, the annular end face of the step forming one bearing surface of the hydrodynamic thrust bearing, the shaft having an end flange in the part of larger diameter at the blind end of the bore of the bearing sleeve, the annular end face of the flange facing the annular end face of the step in the bore of the bearing sleeve forming the other bearing surface of the hydrodynamic thrust bearing.

8. A journal gas bearing assembly as claimed in any preceding claim in which the shaft or sleeve is flexibly mounted.

9. A journal gas bearing assembly susbstantially as herein described with reference to and as illustrated in any one of Figures 1 to 4 of the accompanying drawings.

10. A journal gas bearing assembly substantially as herein described with reference to and as illustrated in Figure 5 of the accompanying drawings.

D. S. BOSSHARDT
Chartered Patent Agent
Agent for the Applicants.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1973.
Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1337621 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig. 1.

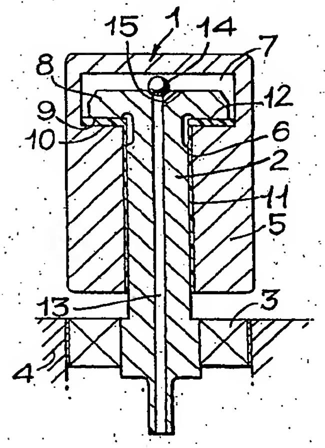


Fig. 2.

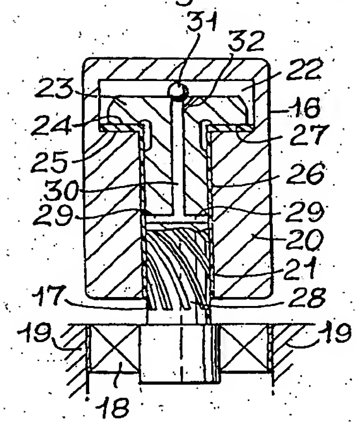


Fig. 3.

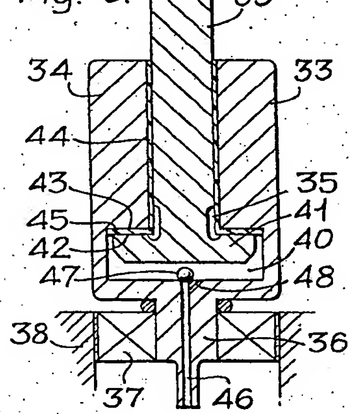
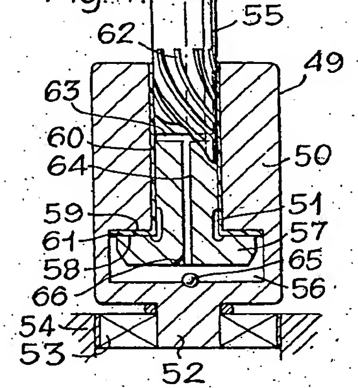


Fig. 4.



1337621 COMPLETE SPECIFICATION

2 SHEETS This drawing is a reproduction of the Original on a reduced scale

Sheet 2

Fig. 5.